VALIDATING THE RELATIONSHIP BETWEEN URBAN FORM AND TRAVEL BEHAVIOR WITH VEHICLE MILES TRAVELLED

A Thesis

by

RAJANESH KAKUMANI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF URBAN PLANNING

August 2009

Major Subject: Urban & Regional Planning

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Approved by:

Chair of Committee,	Eric Dumbaugh
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ABSTRACT

Validating the Relationship Between Urban Form and Travel Behavior with Vehicle Miles Travelled. (August 2009)

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The validity of the influence of urban form on travel behavior has been a topic of interest in travel behavior research. Empirical research shows that urban form influences travel behavior causing less travel impacts. However, according to the conventional travel impact assessment following the ITE's (Institute of Transportation Engineers) *Trip Generation Handbook*, developments with higher levels of urban form measures will generate a greater travel impacts because they generate higher number of trips. The ITE *Trip Generation Handbook* is typically used as a guideline to estimate the number of trips generated by a development. The hypothesis made in the present research is that a development defined with higher levels of land use mix, street connectivity and residential density will generate a higher number of trips because of the greater accessibility but they will be shorter in length. Therefore, the effective distance travelled will be less even though higher numbers of trips are generated. Considering the distance travelled on a roadway will be an appropriate unit for measuring the travel impacts, the research argues that VMT (Vehicle Miles Travelled) can be a better measurement unit than the number of trips to validate the influence of urban form on travel behavior.

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CHAPTER I

INTRODUCTION

BACKGROUND

The detrimental effect of transportation demand on the performance of transportation system is increasing at an alarming rate which is evident from the fact that urban Americans have experienced an increase of 220 million hours of travel time and 140 million gallons of gas consumption from 2004(*1*). The increasing trend of traffic congestion is one of the crucial issues often addressed in transportation research and various solutions are offered to restore the efficiency of transportation system. Most common solutions of travel demand management are toll roads, ride sharing programs, public transportation, telecommuting etc, but the growth trend of mean distance between origins and destinations suggests that households are travelling longer distances to fulfill their travel needs (*shopping, recreation, work*). This gave motivation to acknowledge that trip making is a derived demand and people travel to a destination to fulfill their travel needs. Since the travel destinations are associated with specific land uses and they are the activity centers to satisfy the specific needs, relation between land use and transportation is acknowledged by forming a link between urban form and travel behavior. So, urban forms have been given a new design approach with mix of land uses, greater street connectivity and higher built form density intending that households can fulfill their travel needs at a closer distance from their location and subsequently reduce

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This thesis follows the style of *Transportation Research Record*.

travel distance. But, there are contrasting opinions regarding the effectiveness of urban form measures in reducing the travel demand and the argument is based on a fact that greater levels of land use mix, built form density and street connectivity will generate more number of trips. Since the conventional travel impact assessment states that travel impacts are proportional to the number of trips generated, it is argued that higher levels of urban form measures will cause higher travel impacts, so there will be a negative influence of urban form on travel behavior. The present research identifies that trips generated in neighborhoods with greater levels of land use mix, street connectivity and built form density might be high but they might also be shorter in length because of greater accessibility. Considering the distance travelled on roadway will be an appropriate unit for measuring the travel impacts, the research argues that VMT might be a better unit than number of trips to validate the influence of urban form on travel behavior.

RESEARCH METHODOLOGY

Methodology adopted for the study is to validate the relationship between urban form and travel behavior with vehicle miles travelled (VMT). The study hypothesizes that greater land use mix, street connectivity and built form density might generate higher frequency of trips but they will be shorter in length. So, the conventional travel impact assessment with number of trips as a unit of measurement state those locations with high land use mix, street connectivity and density causes greater travel impacts even though they are contributing less VMT. The research study is designed to find the response of VMT and trips with respect to various urban form measures and find if land use mix, street connectivity and density is associated with higher number of trips and less VMT. Land use mix, street connectivity and residential density are considered as urban form variables and the relationship with trips and VMT is analyzed by regressing the urban form variables on trips and VMT separately. The relationship is analyzed at three circular buffer ranges around the household's location.

RESEARCH OBJECTIVES

Three main objectives are formulated to address the present research problem and they are as follows:

- Propose an appropriate unit of measurement for assessing the influence of urban form factors on travel behavior of households.
- Find the relationship between household trips and vehicle miles travelled (VMT).
- Compare the differences in the influence of urban form measures on travel behavior of households when analyzed with trips and VMT.

INTENDED BENEFITS FROM THE RESEARCH

Influence of urban form on travel behavior

Urban form influence on travel behavior has been ambiguous because of different set of criteria taken to represent the travel behavior i.e. number of trips and vehicle miles travelled (VMT). The present research compares the response of trips and VMT with respect to the variation in the urban form measures and presents an appropriate variable to address the influence of urban form on travel behavior.

A new unit of measurement for analyzing the travel impacts: The research states that the travel impact study could be biased if the vehicle trips are considered as the criteria in assessing the travel impacts and might impose higher impacts on household who are actually contributing less than that. So, the research proposes that if VMT is considered as the criteria then the households might be treated fairly in the travel impact assessment.

THESIS OVERVIEW

This thesis is divided into six chapters. Chapter I provide introduction, research objectives, research benefits and description of research methodology. Chapter II summarizes different literature studies on the built form and travel behavior relationship. Chapter III discusses the data used for this study and how the data is collected and refined for the analysis. Chapter IV presents relevant statistical results obtained in finding the relationship between urban form measures and travel behavior variables (VMT, trips). In Chapter V, final results and discussions for the data analysis are presented in detail. In Chapter VI, Conclusions and the future research associated with the results are discussed in brief.

CHAPTER II

LITERATURE REVIEW

The goal of research on urban form and travel behavior is to provide a policy framework for transportation demand management i.e., how much savings in automobile travel can be expected, which in turn reduces air pollution, congestion etc (*2*). Since air pollution and congestion are typical forms of travel impacts, influence of travel behavior through urban form is indirectly addressing the travel impacts. So, measuring the influence of urban form on travel behavior is as critical as the methodology adopted for assessing the travel impacts. The present research identifies that a conventional travel impact assessment guided by ITE's trip generation manual follows number of trips as a travel behavior variable and argues that VMT might be an appropriate unit by hypothesizing that larger number of trips might be associated with lesser VMT. So, methodology adopted for this study is to observe the response of number of trips and VMT with respect to the variation of urban form measures and find if higher number of trips is associated with less VMT.

METHODOLOGY OF ITE'S *TRIP GENERATION HANDBOOK* FOR TRAVEL IMPACT ANALYSIS

The impact of a development on the performance of a transportation system like the increase in traffic volumes (*changes in level of service of roadways*), changes in traffic operations and threat to traffic safety are typically considered as travel impacts

(*3*). The local agencies, Cities or any governing bodies permitting a development in their jurisdiction are responsible for reviewing the travel impacts of a development and they will formulate a travel impact study requirements. The impact of any development, large or small, on the transportation system depends on the number of trips generated by the development and the routes taken to and from the site (3). Typically, methodology developed for a travel impact assessment is based on number of trips and follows the criteria set by the ITE's *Trip Generation Handbook* for estimating the trips generated by a land use. According to ITE's *Trip Generation Handbook* (*4*), the number of trips generated by a land use is a function of various trip generating variables like gross floor area, household income, employees, seats, dwelling units etc. Based on the type of land use and location, a linear relationship is formed between number of trips and trip generating variables to estimate trips associated with a particular land use. This is same as discounting any effect of household accessibility to out-of-home activities as a factor in trip generation (*5*). If the number of vehicular trips is considered to measure the travel impact and ITE's *Trip Generation Handbook* is followed to estimate the number of trips generated by a development, then travel impact analysis is not responsive to the influence of location attributes (*connectivity, land use mix, density*) of the development i.e. reducing the travel distance of the trips. To form a basis for the argument made in the research that higher frequency of trips might be associated with lesser VMT, appropriate review is done on relevant past research on the influence of urban form measures on trips and VMT.

INFLUENCE OF URBAN FORM ON TRIP GENERATION RATES OF THE HOUSEHOLDS

The influence of urban form on travel behavior has been researched in various ways subjecting to the conditions of the availability of data and the research problem. Empirical studies relating built form and travel behavior can be organized along three dimensions: (i) types and purposes of travel behavior (ii) scale at which built form is measured and analyzed (*aggregate or disaggregate*), and (iii) types of built form characteristics (*6*). Trip frequency is one of the components to measure the travel behavior and it denotes the rate at which trips are made between origins and destinations. A trip is defined as a one way movement between an origin and destination (*7*). The influence of urban form on frequency of trips gives insights on how frequent households are making trips to land use destinations if they are located at an accessible distance. In the context of urban form, accessibility is defined as the connectivity provided by the transportation system to a pattern of activities determined by their quantity, quality and variety (*8*). According to Handy (*8*), households with higher accessibility to greater variety of land use destinations tend to contribute higher trip frequencies and most of those trips are made to convenience stores and regional shopping centers. So, a greater range of choice seems to be associated with higher trip frequencies, possibly inducing more trips that would not have been made given more limited choices (*8*). In providing the accessibility to commercial land uses, role of street connectivity is given utmost importance intending that greater street connectivity will ensure more number of travel options to reach the destination and also reduces the distance between origin and destination. The analysis done by Crane and Crepeau(*9*) revealed that street connectivity measures (grid pattern) didn't showed significant relationship with the trip making behavior of households, but the level of mobility associated with street network system is positively correlated with trip frequency where as length of trip is negative correlated. So, according to Crane and Crepeau, length of trip and time taken to accomplish the trip are the two main attributes which are influencing the trip making pattern of household. Regarding the influence of land use, their research states that proportion of commercial land uses shows a significant relationship with the trip frequency with greater mix of land uses is associated with higher trip frequencies. The concluding remarks which can be made from the perspective of Crane and Crepeau is that the trip frequency of households is associated with land uses which can be accessed with less amount of travel time. But, reacting to the Crane's statement that type of street network doesn't influence the trip frequency, it can be argued that for a certain amount of travel demand, if there exists any relationship between travel time and street network. If so, then there is a possibility that type of street network might influence the trip pattern of households. Very few research attempts have been made to find the influence of all the urban form measures together on the frequency of trips. The influence of urban form on work trips is not given much importance because of the larger percentage of non work trips in a typical trip pattern of a household, but Frank (*10*) analyzed the trip generation of work trips with respect to employment density, population density, and land use mix and a positive correlation is revealed. According to the aggregate analysis done by Cervero and Radisch (*11*), neighborhoods with greater land use mix, street connectivity and built form density reported higher non-work trips, the study stated that neighborhood characteristics add significant explanatory power when socio-economic differences are controlled. The possible influence of household's characteristics on the trip making behavior is addressed in few researches. Analysis by Ewing and Cervero (*6*) found greater association between household characteristics and trip frequencies, Wegener and Furst (*12*) (1999) stated that fixed time and money budget constraints influenced the trip making patterns of households. Fredman and Shefer (*13*) modeled the trip patterns with various land use scenarios and income, the results suggested a significance relationship between higher trip frequencies and household income. Identifying the methodology followed by the ITE trip generation manual, Ewing et al. (*5*) analyzed the trip generation rates with respect to urban form measures (*density, land use mix, accessibility*) and found that trip rates are not responsive to the variation in urban form measures. But the land use approach taken by Ewing et al is towards the job-housing balance and did not exactly targeted on land uses typically visited by the households. A contrasting perspectives have been given by Handy(*8*) and Ewing(*5*) regarding the influence of urban form on trip rates and one distinction which can be made between these researches is the land use destinations choice set collected for each household. The land uses collected by Handy consists of the places frequently visited by the household and the results are based on the influence of accessibility provided to those land uses on trip frequencies, where as Ewing's data doesn't include the land uses which attracts the frequent trips made by the households.

So, an extensive review on past research reveals a clear indication of individual's choice in the selection of locations to fulfill their travel needs (*for shopping, recreation etc*). Referring to the relevance of utility maximization theory to the travel choice of households (*14*), it can be inferred that in the case of influence of urban form on trip frequencies there might be a possibility that the households are maximizing their utility by making frequent trips to closer land use destinations. Considering the reduction of trip distance is one of the choices which maximize the utility of households, there is a possibility that households are trying to minimize the trip distance by travelling to closer land use destinations no matter how many trips they are making in a day. So, it is worth considering the travel distance associated with the frequent trips caused by the urban form. As a travel behavior variable, VMT is not as common as vehicle trips because of data complexities associated in collecting the information on VMT contributed by each household.

Significant part of the influence of urban form on travel behavior research concentrated on vehicular trips or VMT, but very few researches revealed the relationship between trips and VMT in the same research context. Handy (*15*) tested the hypothesis that accessibility levels will be negatively correlated with travel distance (VMT) and positively correlated with frequency of trips. The results showed that higher levels of accessibility levels are associated with shorter shopping distances and higher trip frequencies. So, an inverse relationship is found between trips and VMT. **Figure 1** shows the relationship between trips and accessibility, **Figure 2** shows the response of VMT with respect to the degree of accessibility. Since the research is done by differentiating between various levels of accessibility like regional and local, it is suggested that the tested hypothesis holds good only if the local accessibility is complemented with regional accessibility. Cervero and Kockelman (*16*) found that households living in residential neighborhoods which have higher accessibility to the commercial activities tend to average less VMT. Frank and Pivo (*17*) found that the presence of retail activities within in the neighborhoods is associated with less VMT mostly because of the households preferring other modes of travel like walking, transit etc. Kockelman (*18*) studied the influence of accessibility and land use mix on VMT and a statistically significant relationship is found with higher accessibility and greater land use mix contributing less VMT. Frank's (*9*) analysis of the influence of urban form influence on travel behavior found that employment density, population density and land use mix were positively correlated with number of trips and negatively correlated with trip distance.

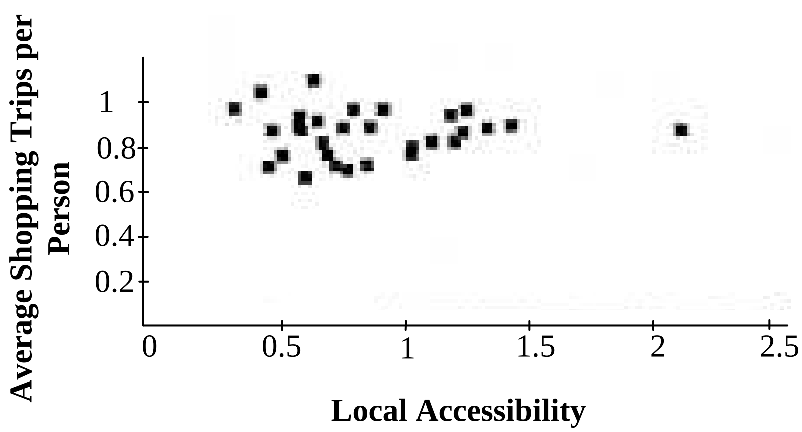

Figure 1. Scatter plots showing the relationship between local accessibility and shopping trips (*15*)

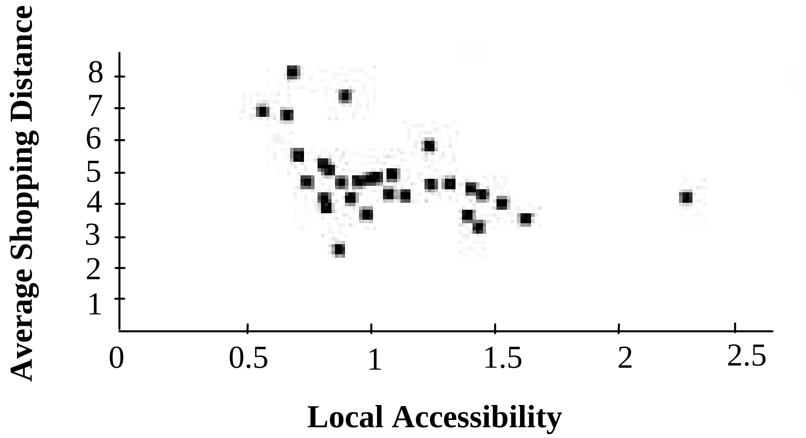

Figure 2. Scatter plots showing the relationship between local accessibility and vehicle miles travelled (*15*)

CONCLUDING REMARKS

Following are the conclusions made after reviewing the past research:

- Past research showed that VMT and trips doesn't have same relationship with respect to the variation in urban form measures.
- Significant amount of research concentrated on number of trips rather than on VMT in analyzing the urban form measures because of the accuracy associated with VMT calculation.
- The influence of urban form measures on VMT and trips is not analyzed in the same context, so making a comparison of the effectiveness between VMT and trips as a travel impact unit is not clear.

CHAPTER III

DATA COLLECTION

FOCUS OF STUDY

The focus of study for the research is Travis County which is located in Central Texas, United States. Based on the U.S. Census Bureau, county area is about 1,022 square miles with a population of 921,006.

UNIT OF ANALYSIS

The units of analysis for the study are households located in Travis County. Relevant data about the households is obtained from the travel behavior survey (2006) which was conducted by TxDOT (Texas Department of Transportation) consisting of household's socio-demographic, economic and travel pattern data for a typical working day. Based on the requirements of study, data is extracted and analyzed to address the research problem stated. The sample size of the travel behavior survey is 1499 which consists of households who are located in the counties like Bastrop, Caldwell, Hays, Travis, Williamson, Bexar, Comal, Guadalupe, Kendall and Wilson. Since the present study is focusing on Travis County, the final sample size is 791.

METHOD OF EXTRACTING NEIGHBORHOOD CHARACTERISTICS FOR EACH HOUSEHOLD

Apart from the data provided by the travel behavior survey, the present study needs information about neighborhood characteristics of each household which are also termed as urban form measures. The location information of each household is provided in the form of longitude and latitude and they are plotted in Arc GIS as a point shape file with each point representing a household. Urban form measures for each household are extracted by forming circular buffers around each household which are represented as points in the GIS shape file.

VARIABLES CONSIDERED FOR THE STUDY AND THE METHOD FOLLOWED TO EXTRACT THEM

Urban form measures

These are the variables which define the characteristics of the neighborhood. Typically measures like number of intersections, roadway segment lengths and counts, building density, pedestrian facilities, average block length are considered. Based on the data availability and the research problem the urban form measures vary, following is the description of the data collection and analysis of the urban form measures considered for the present research.

Nodes

In the present research a Node is defined as an intersection which is connected to more than or equal to three roadway links. Nodes which meet this criterion are considered as valid nodes. For each household all these valid nodes are calculated within a circular buffer distances of 0.25, 0.5 and 1 mile. The calculated nodes are aggregated at a household level and more number of nodes in a household buffer indicates that the links in that buffer are well connected and hence the household has higher route options and greater accessibility to their surroundings. The GIS data for the street network of Travis County is used as the base data to calibrate the nodes. Network Analyst, one of the Arc GIS extensions is used to generate the node data and intersected with the individual household buffers to extract the node information for each household. **Table 1** shows the descriptive statistics of the nodes calculated for the entire household sample size.

Table 1. Descriptive statistics of nodes calculated for each household

Buffer Radius	No. of HH	Minimum	Maximum	Mean	Std. Deviation
0.25	791	3	36	17.9	10.08
0.5	791	6	89	39.45	22.9
1	791	11	140	64.56	37.39

Land uses

For each household various land uses available in their proximity are analyzed. In the previous researches this is also mentioned as land use mix with the percentage of standard land uses like commercial, industrial, residential etc. But all the commercial uses may not be equal in terms of attracting the household trips. For example, a trip to a grocery store or a convenience store will be very frequent and important part of the daily trips than a trip to a car wash centre or to a DVD store. A typical land use map contains generalized land use information but not about the specific type of usage of the parcel (i.e. restaurant, grocery store, office etc). So database related to the detail usage of the parcel is obtained from the Travis County Appraisal District (TCAD) which has the detail information about the usage of the parcel identified with unique numbers. Since this data is not in the spatial format each parcel identification number is matched with the parcel numbers obtained from the generalized land use parcel data by intersecting with household buffer. The final database contains the detail usage of parcels which are under the buffers of each household. So, rather than generalizing the availability of land use mix for each household, the land uses that plays an integral part of a household's daily activities are identified and calibrated for each household within the circular buffer ranges of 0.25, 0.5 and 1 mile radius. The identified land uses are listed in **Table 2**.

Table 2. Descriptive statistics for the land uses in 0.25, 0.5, 1 mile buffer radius

Land Use	**Min - Max**					
	0.25		**0.5**		**1**	
Restaurants	0	3	0	5	0	6
Fast Food Center	0	1	0	3	0	3
Grocery Stores	0	1	0	2	0	2
Neighborhood Shopping Center	*	*	*	*	0	2
Day Care Center	0	4	0	5	0	5
Schools	*	*	*	*	0	1

- indicates less than 1 and didn't considered as a valid form of representing mean
* indicates that the analysis is not done for the respective buffer.

Residential density measures

The concentration of development around each household is captured in terms of number of residential units in the circular buffer ranges of 0.25, 0.5 and 1 mile. This data is calibrated with the help of the City of Austin utility connection data in the form of GIS point shape file which is overlaid on top of the circular buffers of each household and extracted the number of residential units in each buffer through the intersect tool in Arc GIS. The extracted data is aggregated at each household to get the number of residential units with the specified buffer ranges of each household. The basic descriptive statistics of the residential units' data is presented in **Table 3.**

Table 3. Descriptive statistics of residential density within the circular buffers

Buffer Radius	Minimum	Maximum	Mean	Std. Deviation
0.25	5.00	99.00	44.4962	21.41300
0.5	8.49	182.91	70.7505	35.22117
1	14.12	371.64	141.4665	69.63304

Household trips

Number of household trips is obtained by the travel behavior survey done by TxDOT. The trip data provides number of trips made by the household on the survey day and it is aggregated at the household level for the analysis. The basic descriptive statistics of the household trip data is presented in the **Table 4**.

Table 4. Descriptive statistics of household trips made on the survey day

	Minimum	Maximum	Mean	Std. Deviation
Household Trips	1	21	7.69	4.167

Household VMT

Travel behavior survey is provided with the origins and destinations of each single trip made by the household member. It is provided in the form of geographic co-ordinates (longitude and latitude) and these are converted into ArcGIS point shape file with each point representing an origin or destination of a particular trip. For each household member there will be a series of trips defined by origin and destination points which will be used to calculate the length of all the trips made by each household member on that particular day. The distance between origin and destination is calculated by using the network analyst extension from ArcGIS with street network data of the Travis County as the base data considering that the trips followed this roadway network. Since the exact route taken for each trip by the household member is not known, the shortest possible distance is calculated for each trip by considering that people usually consider the shortest route to reach their destination. The calculated VMT for each household member is aggregated at the household level. Since the household size varies and has high variance, the VMT will be influenced by the size of household. So the VMT per trip is calculated by dividing the VMT by the number of trips made by the household, so this way even though household sizes are different the VMT contribution is measured on a common scale. **Table 5** shows the basic descriptive statistics of the VMT data for all the households in the sample.

Table 5. Descriptive statistics of the household VMT data

HH VMT	Minimum	Maximum	Mean	Std. Deviation
	2.91	92.34	41.4	17.34

VMT by mode split

A household member's VMT through the transit is not same as the VMT though the car because the impact caused on the road varies due to the change in vehicle occupancies of those two modes. So for each household rather than taking a composite VMT, it is split in to various categories based on the mode of travel. This is done based on the mode of travel recorded for each household member's trip during the travel behavior survey. **Figure 3** shows the total Household VMT for automobile, transit and walking trips.

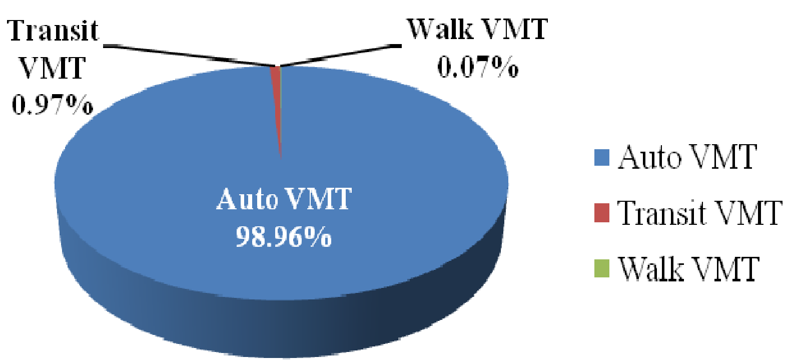

Figure 3. Total household VMT with mode split

The VMT for transit and walking modes is just above 1% of the total Household VMT, so its significance with the urban form and land use measures is not analyzed.

CHAPTER IV

DATA ANALYSIS

Approach to the present research problem is done in twofold, one is to find the influence of the household urban form measures on number of trips made by the household on the survey day and the other one is to validate the same relationship with number of trips replaced with vehicle miles travelled by the household. This problem is approached with multiple regression models by regressing the urban form measures on VMT and trips. The regression analysis is done for three circular buffer ranges separately. The models are presented as equation 1 and 2. The detail descriptions of the variable codes in the models are presented in **Table 6.**

Table 6. Detail description of variable codes in the models

Variable Code	Detail Description of the Code
Groc	Grocery Stores
Rest	Restaurants
Conv	Convenience Stores
DayC	Day Care Centers
FFood	Fast Food Centers
Node	Number of Intersections
ResUni	Number of Residential Units
Sch	Number of Schools
Neigh_sh	Neighborhood Shopping Centers

HYPOTHESIZED MODEL DESCRIPTIONS

Model 1

Influence of household's urban form characteristics on number of vehicular trips. This relationship analyzes the response of the number of trips with respect to the variation in density, land use and street connectivity measures. **Equation 1** shows the relationship between number of trips and urban form characteristics.

$$\textbf{Number of trips} = \beta_0 + \beta_1(Rest)+\beta_2(Groc)+ \beta_3(Conv) + \beta_4(DayC) + \beta_5(FFood) + \beta_6(Node) + \beta_7(ResUni) + \beta_8(Sch)+ \beta_9(Neigh\_Sh) + e \qquad (1)$$

Model 2

Influence of household's urban form characteristics on vehicle miles travelled (VMT). This relationship analyzes the response of VMT with respect to the variation in density, land use and street connectivity measures. **Equation 2** shows the relationship between VMT and urban form characteristics.

$$\textbf{VMT} = \beta_0 + \beta_1(Rest)+\beta_2(Groc)+ \beta_3(Conv) + \beta_4(DayC) + \beta_5(FFood) + \beta_6(Node) + \beta_7(ResUni) + \beta_8(Sch)+ \beta_9(Neigh\_Sh) + e \qquad (2)$$

The initial observation of the models showed that the data has some outliers which are skewing the results and hence the violation of some of the assumptions of the linear regression model. So the preliminary observation of the data is done on the outliers to study if they form a valid contribution to the model. The following observations have been made from studying the outliers:

- Some of the households are located in high density locations where a building has extremely higher number of housing units and standing out as an outlier.
- Few households made special trips on the survey day which contributed to the increase in number of trips and subsequent vehicle miles travelled.

Since the outliers are found to be valid data points they are not removed from the data set and at the same time the assumptions of the regression are not met with the outliers. So, valid data transformations are made to test the assumptions of multiple regressions. The procedures followed for the data transformations and the assumptions tested for the models are presented in **Appendix A**.

ANALYSIS OF REGRESSION MODELS

The hypothesized models are analyzed with multiple regression analysis and the steps for each model are as follows:

- Testing of assumptions for regression analysis

- Testing of relationship between dependent and independent variable
- Estimation of regression parameters

Since the land use data is discrete and linear regression requires the data to be continuous, the data is dichotomized. For instance, if a household has no restaurants in their quarter mile buffer radius then the corresponding value is considered as “0” and if the household has more than or equal to one restaurant then the value is considered as “1”. This process of coding the data is also called as dummy coding and it is followed for all the land use variables. Regression analysis is done by incorporating those dummy coded variables.

ANALYSIS FOR MODEL 1

Hypothesized model

$$\textbf{Number of trips} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest) + \boldsymbol{\beta_2}(Groc) + \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood) + \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch) + \boldsymbol{\beta_9}(Neigh\_Sh) + e \quad (1)$$

Tests for relationship between dependent and independent variables

Through this test the relationship assumed between independent and dependent variables is tested. Null hypothesis is presented as equation 3 and the test results for three mile buffers are presented in **Table 7**, **Table 8** and **Table 9**.

$$\mathbf{H_0}: \beta_1=\beta_2=\beta_3=\beta_4=\beta_5=\beta_6=\beta_7=\beta_8=\beta_9 = 0 \quad (3)$$

Test results

Table 7. Test results for quarter mile buffer radius in model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	9,494.499	7	1,356.357	252.315	.000(a)
Residual	4,203.755	782	5.376		
Total	13,698.254	789			

Table 8. Test results for half mile buffer radius in model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6,939.922	7	991.417	114.632	.000(a)
Residual	6,771.949	783	8.649		
Total	13,711.871	790			

Table 9. Test results for one mile buffer radius in model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	6,126.482	9	680.720	70.164	.000(a)
Residual	7,577.091	781	9.702		
Total	13,703.573	790			

Since the null hypothesis is rejected, the hypothesized model 1 is significant in all the radii. So the significant model indicates the preliminary relationship between the dependent and the independent variables is a valid assumption.

REGRESSION RESULTS FOR PARAMETERS OF THE MODEL 1

Regression results for the parameters of model 1 for the three buffer radii are presented in **Table 10**, **Table 11** and **Table12**.

Test results for model 1

Number of trips = $\boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest) + \boldsymbol{\beta_2}(Groc) + \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood)$

$+ \ \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch) + \boldsymbol{\beta_9}(Neigh\_Sh) + e$ (1)

Table 10. Regression results of model 1 for quarter mile buffer

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	0.935	0.215	4.346	0.000
Restaurants	0.481	0.209	2.302	0.022
Grocery stores	0.021	0.223	0.094	0.925
Convenient stores	0.280	0.169	1.663	0.097
Day care centers	-0.055	0.170	-0.325	0.745
Fast food centers	1.068	0.194	5.513	0.000
Intersections	0.285	0.011	26.683	0.000
residential units	0.024	0.004	5.264	0.000

Dependent Variable: Number of Trips
R^2 = .69

Table 11. Regression results of model 1 for half mile buffer

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	1.982	0.276	7.173	0.000
Restaurants	-0.025	0.249	-0.100	0.920
Grocery stores	-0.244	0.279	-0.874	0.382
Convenient stores	0.589	0.213	2.759	0.006
Day care centers	-0.079	0.212	-0.370	0.711
Fast food centers	0.007	0.228	0.031	0.975
Intersections	0.118	0.006	20.723	0.000
residential units	0.012	0.003	3.485	0.001

Dependent Variable: Number of Trips
R^2 = .506

Table 12. Regression results of model 1 for one mile buffer

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	22.823	1.236	18.460	0.000
Restaurants	0.776	0.653	1.190	0.235
Grocery stores	-0.204	0.551	-0.371	0.711
Convenient stores	0.134	0.588	0.228	0.820
Day care centers	0.386	0.584	0.662	0.508
Fast food centers	-0.383	0.583	-0.656	0.512
Intersections	-0.154	0.008	-19.610	0.000
residential units	-0.028	0.004	-6.582	0.000
schools	-0.045	0.517	-0.088	0.930
Neighborhood shopping centers	-0.364	0.538	-0.676	0.499

Dependent Variable: Number of Trips
R^2 = .447

ANALYSIS FOR MODEL 2

Hypothesized model 2

$$\mathbf{VMT} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest) + \boldsymbol{\beta_2}(Groc) + \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood) + \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch) + \boldsymbol{\beta_9}(Neigh\_Sh) + e \quad (2)$$

Tests for relationship between dependent and independent variables

Through this test the relationship assumed between independent and dependent variables is tested. Null hypothesis is presented as equation 3 and the test results for three mile buffers are presented in **Table 13**, **Table 14** and **Table 15**.

Test results for model 2

H_0: $\beta_1=\beta_2= \beta_3= \beta_4= \beta_5= \beta_6= \beta_7= \beta_8=\beta_9 = 0$

Table 13. Test results for quarter mile buffer radius in model 2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	37,437.103	7	5,348.158	106.925	.000(a)
	Residual	39,114.115	782	50.018		
	Total	76,551.217	789			

Table 14. Test results for half mile buffer radius in model 2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31,275.368	7	4,467.910	75.613	.000(a)
	Residual	46,266.756	783	59.089		
	Total	77,542.124	790			

Table 15. Test results for one mile buffer radius in model 2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38,105.240	9	4,233.916	82.270	.000(a)
	Residual	40,192.931	781	51.463		
	Total	78,298.171	790			

Since the null hypothesis is rejected, the hypothesized model 2 is significant in all the radii. So the significant model indicates the preliminary relationship between the dependent and the independent variables is a valid assumption.

REGRESSION RESULTS FOR PARAMETERS OF THE MODEL 2

$$\mathbf{VMT} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest) + \boldsymbol{\beta_2}(Groc) + \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood) + \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch) + \boldsymbol{\beta_9}(Neigh\_Sh) + e \qquad (2)$$

The regression results of model 2 for all the three buffers are presented in **Table 16**, **Table 17** and **Table 18**.

Table 16. Regression results of model 2 for quarter mile buffer

	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	24.082	0.657	36.680	0.000
Restaurants	-0.782	0.637	-1.227	0.220
Grocery stores	0.061	0.679	0.090	0.929
Convenient stores	-1.363	0.514	-2.652	0.008
Day care centers	-0.684	0.520	-1.317	0.188
Fast food centers	-1.935	0.591	-3.276	0.001
Intersections	-0.485	0.033	-14.890	0.000
residential units	-0.096	0.014	-7.009	0.000

Dependent Variable: VMT
R^2 = .48

Table 17. Regression results of model 2 for half mile buffer

	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	22.486	0.722	31.137	0.000
Restaurants	-0.095	0.651	-0.147	0.884
Grocery stores	0.979	0.730	1.340	0.181
Convenient stores	-1.456	0.558	-2.612	0.009
Day care centers	0.444	0.555	0.800	0.424
Fast food centers	-0.948	0.596	-1.590	0.112
Intersections	-0.217	0.015	-14.510	0.000
residential units	-0.054	0.009	-6.101	0.000

Dependent Variable: VMT
R^2 = .403

Table 18. Regression results of model 2 for one mile buffer

	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	2.679	0.537	4.991	0.000
Restaurants	-0.440	0.283	-1.551	0.121
Grocery stores	0.043	0.239	0.181	0.857
Convenient stores	0.106	0.255	0.417	0.677
Day care centers	-0.199	0.254	-0.785	0.433
Fast food centers	-0.109	0.253	-0.431	0.667
Intersections	0.069	0.003	20.249	0.000
residential units	0.005	0.002	2.587	0.010
Schools	0.201	0.225	0.894	0.372
Neighborhood shopping centers	0.413	0.234	1.765	0.078

Dependent Variable: VMT
R^2 = .48

RELATIONSHIP BETWEEN THE TRIPS AND VMT

The scatter plots of trips vs. VMT shows non-linear relationship, so the curve fit estimation is used to find the accurate relationship.

Curve fit estimation

The curve estimation is a curve fitting procedure trying with all possible non-linear relationships like logarithmic, quadratic, inverse, power and exponential and select the appropriate one based on the goodness of fit. Based on the results quadratic and logarithmic relationships holds good between the household trips and the VMT. The test results for curve fit estimation are presented in **Table 19.**

Table 19. Test results for the curve estimation

Equation	Model Summary					Parameter Estimates		
	R Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	.573	1057.8	1	788	.000	65.674	-3.151	
Logarithmic	.616	1266.5	1	788	.000	83.446	-22.406	
Quadratic	.626	659.6	2	787	.000	77.022	-6.372	.176
Power	.493	766.0	1	788	.000	103.833	-.543	
Growth	.518	847.8	1	788	.000	4.249	-.081	
Exponential	.518	847.8	1	788	.000	70.057	-.081	
Logistic	.518	847.8	1	788	.000	.014	1.085	

Results of regression models

The results of regression models are summarized as follows:

- At quarter mile buffer radius, all the urban form measures except grocery stores and day care centers showed significant relationship with trips and VMT. The relationship showed that greater levels of urban form measures are associated with higher frequency of trips and lesser VMT.
- But the relationship between urban form measures and the travel behavior variables (trips and VMT) is not consistent in half mile and one mile buffer as the land use variables are significant in those buffers.
- Density and street connectivity are significant with trips and VMT in all the buffers and showed a consistent direction of relationship with trips and VMT.

Summarized results for the regression developed are presented in **Table 20.**

Table 20. Summary of regression results

	Quarter Mile Buffer				**Half Mile Buffer**				**One Mile Buffer**			
Urban Form Variables	**Trips**		**VMT**		**Trips**		**VMT**		**Trips**		**VMT**	
	Sig.	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**	**Sig.**	**Beta**
Restaurants	**0.02***	0.48	0.22	-0.78	0.92	-0.02	0.88	-0.09	0.23	0.77	0.12	-0.440
Grocery stores	0.92	0.02	0.92	0.06	0.38	-0.24	0.18	0.97	0.71	-0.20	0.85	0.043
Convenient stores	0.09	0.28	**0.00***	-1.36	**0.00***	0.58	**0.00***	-1.45	0.82	0.13	0.67	0.106
Day care centers	0.74	-0.05	0.18	-0.68	0.71	-0.07	0.42	0.44	0.50	0.38	0.43	-0.199
Fast food centers	**0.00***	1.06	**0.00**	-1.93	0.97	0.00	0.11	-0.94	0.51	-0.38	0.66	-0.109
Intersections	**0.00***	**0.28***	**0.00**	**-0.48**	**0.00***	**0.11**	**0.00***	**-0.21**	**0.00***	**-0.15**	**0.00***	**0.069**
residential units	**0.00***	**0.02***	**0.00***	**-0.09**	**0.00***	**0.01**	**0.00***	**-0.05**	**0.00***	**-0.02**	**0.01***	**0.005**
School	x	**x**	**x**	**x**	**x**	**x**	**x**	**x**	0.93	-0.04	0.372	0.201
Neighborhood shopping Centers	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	0.49	-0.36	0.07	0.413

‘x’ denotes that the variable is not measured in the buffer.

‘*’ denotes the significance at 95% confidence

CHAPTER V

RESULTS AND DISCUSSION

Regression models developed in the data analysis part of this research have analyzed the relationship between urban form and travel behavior by forming a linear relationship between urban form measures and trip making behavior of households. The trip making behavior is measured in number of trips and vehicle miles travelled, and urban form variables are measured in land uses, street connectivity and residential density. Results of regression models gave some insights on the influence of urban form measures on trips and VMT. These insights will be used as an evidence to extend the argument made in the research statement that higher frequency of trips is associated with lower levels of VMT.

RELATIONSHIP BETWEEN NUMBER OF TRIPS AND VEHICLE MILES TRAVELLED

Curve fit estimation is done to find the existence of specific direction of relationship between number of trips and VMT. The relationship is analyzed by taking trips as dependent variable and VMT as independent variable. The results showed that there is a logarithmic (negative exponential) relationship between number of trips and VMT. The relationship showed that the VMT is gradually increasing as the number of trips is decreasing. It shows an indication that fewer numbers of trips are causing greater levels of VMT.

INFLUENCE OF URBAN FORM MEASURES ON NUMBER OF HOUSEHOLD TRIPS

The regression model between number of trips and urban form measures explained about 69 %, 50.6% and 44.7 % of the relationship in quarter mile, half mile and one mile buffer respectively. Following are the specific observations made after analyzing the influence of specific urban form measures on number trips.

Street connectivity

Number of street intersections is considered as a measure of street connectivity. Street intersections variable in the regression model is statistically significant in all the buffers and the direction of relationship showed that number of intersections is directly proportional to the number of trips. It means that, if the households are located in a neighborhood with greater street connectivity, then their frequency of trips is high.

Residential density

Number of residential units is considered as a measure of built form density. The density variable in the regression model is statistically significant in all the buffers and the direction of relationship showed that higher number of residential units is associated with higher number of trips.

Land uses

The influence of land uses on number of trips is statistically significant in quarter mile buffer and the direction of relationship showed that higher number of land uses is associated with higher number of trips. So, households with greater accessibility to higher number of land use destinations are making higher number of trips. But this relationship is not consistent in all the buffers as the land use variables are not statistically significant. Summarizing the influence of urban form on trips, street connectivity and residential density showed better relationship than land uses.

INFLUENCE OF URBAN FORM MEASURES ON VEHICLE MILES TRAVELLED (VMT)

The regression model between number of trips and urban form measures explained about 48%, 40% and 48 % of the relationship in quarter mile, half mile and one mile buffer respectively. Following are the specific observations made after analyzing the influence of specific urban form measures on vehicle miles travelled (VMT).

Street connectivity

Street intersections variable in the regression model is statistically significant in all the buffers and the direction of relationship showed that number of intersections is inversely proportional to VMT. It means that, if the households are located in a neighborhood with greater street connectivity, then they are contributing less VMT.

Although it is a partial explanation, the relationship shows a possibility that higher street connectivity might be reducing the distance travelled to land use destinations.

Residential density

The density variable in the regression model is statistically significant in all the buffers and the direction of relationship showed that higher number of residential units is associated with less amount of VMT.

Land uses

The influence of land uses on VMT is not significant in all the buffers except fast food centers and convenient stores which are significant in quarter mile buffer. The direction of relationship between land uses and VMT shows that higher number of land uses is associated with lower levels of VMT, but the relationship is not statistically significant. So, the influence of land uses on VMT is inconclusive. Summarizing the influence of urban form on VMT, the relationship between land uses and VMT is weak. Street connectivity and density showed consistent relationship with VMT.

CONCLUDING REMARKS

The influence of urban form measures on number of trips is very much clearer than on VMT. Observing the relationship between trips and VMT (negative exponential), association of higher number of trips with less VMT is still a valid argument to be continued with an extensive set of data on land uses.

CHAPTER VI

FINDINGS AND CONCLUSIONS

The goal of this research is to address the influence of urban form on travel behavior by validating VMT as a unit of measurement. Two separate regression models are analyzed for comparing the response of number of trips and VMT with respect to the variation of urban form measures and find if urban form measures shows a contrasting relationship between trips and VMT. Following is the summary of findings made from the research study:

URBAN FORM INFLUENCE ON TRAVEL BEHAVIOR

Urban form influence on travel behavior should be validated by revising the existing criteria of travel impact assessments. The influence of urban form on travel behavior would be ambiguous because of contrasting research perspectives which doesn’t have similar criteria in measuring the travel impacts. Present study showed that the influence of urban form on travel behavior is not same when the travel behavior is measured in trips and VMT. Urban form measures did showed greater influence on number of trips with households making higher number of trips when they their locations are defined by higher levels of land use mix, street connectivity and residential density. The relationship between urban form measures and VMT is not significant which can raise a question that higher number of trips is not associated with lower levels of VMT. But trips and VMT are related in such a way that higher number of trips is associated with lower levels of VMT, and this can be recalled from the relationship that trips and VMT have negative exponential relationship with fewer trips contributing higher VMT levels. Even though significant number of land uses did not showed influence on the travel behavior variables, the relationship between trips and VMT shows an indication that a comprehensive data on land use might provide better insights on urban form influence on VMT.

LIMITATIONS OF THE STUDY

The limitations of the study are as follows:

- This study is limited to the travel behavior of the sample household’s located in Travis County, but the travel patters will differ by location, culture and several socio-economic factors, so the study on VMT of various household’s located in various geographical locations will give much accurate results.
- The land use data for the present research is collected based on the quantity and did not represented the quality of the land uses. Since the quality of land uses also plays an important role in attracting the trips, comprehensive information on land use comprising of quantity and quality might improve the results.
- The survey is done is done by random sampling of households living in Travis County and the selection of the samples is not intended to address the present research problem. So, the generalized household travel behavior survey didn’t address the entire information relevant to the research study.

FUTURE RESEARCH

This research may not be a holistic way of presenting the importance of VMT over the number of trip in the travel impacts analysis because travel behavior is quite unpredictable and it differs from region to region. So further study is recommended with sample size collected specifically for evaluating the household VMT and that study should involve research on various parts of the country because travel behavior cannot be predicted based on a particular geographical location.

Summary of issues which can be addressed in the future research are listed as follows:

- Relationship between trips and VMT should be taken as a motivation for further study on validation of relationship between land use and VMT.
- Analysis of present research problem with an extensive data on land uses which can be rank ordered based on the quality of services they provide for the customers.
- Further validation of ITE’s travel impact study procedures by making it responsive to location characteristics of the households.

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APPENDIX A

TESTING THE ASSUMPTIONS OF MULTIPLE REGRESSION MODELS

Box-Cox Transformations

Box-Cox transformation is a procedure of transforming the data from one space to another by using power functions. Transformations are done with minimum variation in the data and improve the correlation between the variables. The main goal of the data transformation is to check for the assumptions of the linear regression with minimum possible transformation of the data. Since the dependent variable is transformed and no longer has the same interpretation as before the R^2 and regression co-efficient are not meant to predict the model. In the present cases of regression the dependent variables are transformed by using power functions and it is shown below:

Transformed Variable (dependent) = (untransformed variable) λ

The data is parsed with the help of SPSS syntax written to perform the power transformations of the data. Based on the results of the Box-Cox transformation procedure following λ values are suggested to transform the data for model 1 and model2 and presented in **Table 21.**

Table 21. Suggested λ values for the data transformations

Model Number	Suggested λ values for the transformation
Model 1	0.5
Model 2	-0.1

TESTS TO VERIFY THE ASSUMPTIONS OF LINEAR REGRESSION MODEL

Tests for the Normality of residuals – Kolmogorov-Smirnov Test

Visual method of looking at the Q-Q plots and histograms is not done to check for the normality assumption because of the bigger sample size the Q-Q plots might look normal but it might be deviating from the normal to a greater extent. So Kolmogorov-Smirnov Test is done to test the normality of the residuals. Since the sample size of the data is more than 50, Kolmogorov-Smirnov test is preferred to the Shapiro-Wilk Test.

Hypothesis for the test

H_0: Residuals are normal

H_a: Residuals are not normal

TEST RESULTS FOR MODEL (1)

Number of trips = $\boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest) + \boldsymbol{\beta_2}(Groc) + \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood) + \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch) + \boldsymbol{\beta_9}(Neigh\_Sh) + e$ (1)

Table 22. Test results for the residuals normality test - quarter mile buffer radius in model 1

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.025	781	.200	.998	781	.346

Table 23. Test results for the residuals normality test - half mile buffer radius in model 1

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.031	791	.075	.994	791	.20

Table 24. Test results for the residuals normality test- one mile buffer radius in model 1

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.034	781	.028	.995	781	.016

The null-hypothesis is accepted at 95% confidence level for quarter mile and half mile buffer radius and hence the residuals are normal. But the hypothesis for one mile radius is accepted only at 99% confidence level.

TEST RESULTS FOR MODEL (2)

$$\mathbf{VMT} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(Rest)+\boldsymbol{\beta_2}(Groc)+ \boldsymbol{\beta_3}(Conv) + \boldsymbol{\beta_4}(DayC) + \boldsymbol{\beta_5}(FFood) + \boldsymbol{\beta_6}(Node) + \boldsymbol{\beta_7}(ResUni) + \boldsymbol{\beta_8}(Sch)+ \boldsymbol{\beta_9}(Neigh\_Sh) + e \qquad (2)$$

Table 25. Test results for the residuals normality test - quarter mile buffer radius in model 2

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.031	775	.076	.993	775	.34

Table 26. Test results for the residuals normality test - half mile buffer radius in model 2

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.038	777	.012	.993	777	.267

Table 27. Test results for the residuals normality test - one mile buffer radius in model 2

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Standardized Residual	.026	778	.200	.996	778	.027

The null hypothesis is accepted for quarter mile and half mile buffers, but rejected for one mile buffer. So residuals are normal for quarter mile and half mile buffers.

Co-linearity between the independent variables

Co-linearity between the independent variables is tested by using method called Variance Inflation Factor (VIF). It is an index to measure the degree of variance of a coefficient because of the presence of co-linearity in the independent variables. The VIF value approaching 10 is typically considered as the potential presence of the co-linearity between the independent variables. Test results for Model 1 are presented in **Table 28, Table 29 and Table30**.

TEST RESULTS FOR MODEL (1)

Table 28. Test results of co-linearity diagnostics for the quarter mile buffer radius

Variables	Co linearity Statistics	
	Tolerance	VIF
Restaurants	0.901	0.901
Grocery stores	0.973	0.901
Convenient stores	0.988	1.012
Day care centers	0.918	1.089
Fast food centers	0.901	1.099
Intersections	0.913	1.096
residential units in the parcel	0.781	1.281

Table 29. Test results of co-linearity diagnostics for the half mile buffer radius

Variables	Co linearity Statistics	
	Tolerances	VIF
Restaurants	0.898	1.114
Grocery stores	0.599	1.670
Convenient stores	0.762	1.313
Day care centers	0.970	1.030
Fast food centers	0.859	1.164
Intersections	0.906	1.103
residential units in the parcel	0.905	1.105

Table 30. Test results of co-linearity diagnostics for the one mile buffer radius

Variables	Co linearity Statistics	
	Tolerance	VIF
Restaurants	0.892	1.120
Grocery stores	0.723	1.383
Convenient stores	0.984	1.016
Day care centers	0.985	1.015
Fast food centers	0.981	1.020
Intersections	0.742	1.348
residential units in the parcel	0.991	1.009
Schools	0.982	1.018
Neighborhood shopping centers	0.967	1.034

Co-linearity Test Result

Since none of the VIF's is more than 10, there is no multi-co linearity.

Auto correlation

Since the survey is done for a single day and the other data doesn't have relevance to the time, the tests for auto correlation are not done.

VITA

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